# Tarnished Plant Bug (Heteroptera: Miridae) Populations near Fields After Early Season Herbicide Treatment

G. L. SNODGRASS,[1] W. P. SCOTT, C. A. ABEL, J. T. ROBBINS,[2] J. GORE, AND D. D. HARDEE

USDA–ARS, Southern Insect Management Research Unit, Stoneville, MS.

Environ. Entomol. 34(3): 705–711 (2005)

**ABSTRACT** A single herbicide (Trimec® or Strike 3™) application in early season (March or April) was made to marginal areas around fields in 23-km$^2$ test sites of the Mississippi Delta in 1999, 2000, and 2001. The herbicide was used to kill broadleaf weeds in the marginal areas that served as hosts for tarnished plant bugs, *Lygus lineolaris* (Palisot de Beauvois). The herbicide treatment caused a significant reduction in wild host densities in the treated test sites in all 3 yr. Tarnished plant bug populations in treated test sites did not increase significantly in the treated marginal areas during April and May after treatment of the margins in the first 2 wk of March in 2000 and 2001. The herbicide application was made in the first 2 wk of April 1999, and plant bug populations increased in treated marginal areas in this year. The increase was thought to be caused by plant bugs moving to Italian ryegrass, *Lolium multiflorum* Lamarck, a previously unreported plant bug host, which was not affected by the herbicide. Laboratory tests showed that plant bugs would oviposit in flowering or nonflowering ryegrass when caged on ryegrass for a 6-d period. Newly emerged nymphs developed into adults (56%) when reared on floral spikelets of ryegrass, but no adults were obtained when they were reared on ryegrass stems and leaves. Rearing on floral spikelets beginning with third-instar nymphs resulted in 92% adults, whereas third-instar nymphs reared on stems and leaves produced no adults. These results showed that ryegrass could serve as a reproductive host for plant bugs when it flowered during late April and May. Application of the herbicide in March, when ryegrass was not in flower, resulted in no significant increases in plant bug populations on wild hosts (mainly ryegrass) during April and May in 2 yr of the field study.

**KEY WORDS** tarnished plant bug, *Lygus lineolaris*, wild host plants, herbicides

IN THE DELTA REGION of the mid-South, 169 host plant species of the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), have been identified (Snodgrass et al. 1984a, b). Most of these hosts are broadleaf weeds that are used by tarnished plant bugs for food and reproduction when they have flower buds, blooms, or developing seeds. The presence of wild hosts in the winter and spring allows plant bug populations to increase before moving into cotton, *Gossypium hirsutum* L., the main crop damaged by plant bugs in the mid-South (Tugwell et al. 1976, Cleveland 1982, Snodgrass et al. 1984a). Tarnished plant bugs are controlled in cotton exclusively with insecticides and have developed resistance to several classes of insecticides (Snodgrass and Elzen 1995, Pankey et al. 1996, Snodgrass 1996, Hollingsworth et al. 1997). Control methods for plant bugs other than the use of insecticides are needed.

The Delta region of the mid-South is intensively farmed, and only a small area of the land is undisturbed by agriculture. Snodgrass et al. (1991) found that the marginal areas near agricultural fields comprised only 2.4% of the land in a 6.4-km$^2$ area of Washington County, MS. Early-season wild hosts of plant bugs are found in fields used in crop production and in the marginal areas near fields or along ditches and roads. In the mid-1990s, producers began a widespread preplant burndown weed control program in the Delta. In this program, winter and spring weeds within fields are treated with broad-spectrum herbicides in February and March. Additional treatment of the marginal areas around these fields with a broadleaf herbicide could eliminate most early season plant bug hosts in or near the fields.

Control of tarnished plant bugs in a peach nursery in New York by destruction of wild host plants in or near the nursery was tried unsuccessfully in 1912 (Crosby and Leonard 1914). However, several studies have shown that removal of early season broadleaf hosts in orchard laneways and tree rows by mowing or herbicides caused significant reductions in plant bug damage to peaches or apples (Killian and Meyer 1984,

[1] Corresponding author: SIMRU, USDA–ARS, PO Box 346, Stoneville, MS 38776 (e-mail: gsnodgrass@ars.usda.gov).

[2] Delta Research and Extension Center, Mississippi State University, Stoneville, MS.

Atanassov et al. 2002, Hardman et al. 2004). Fleischer and Gaylor (1987) thought that management of selected growth stages of selected host species over a short time frame might result in effective areawide programs for tarnished plant bugs in heavily cropped agroecosystems such as the Highland Rim area of Alabama. Daisy fleabanes (*Erigeron annuus* L. Persoon and *E. strigosus* Muhlenberg ex Willdenow) were singled out as having the densest populations of plant bugs during the time cotton was in an early square growth stage. They thought that management of the two fleabanes could affect plant bug populations in cotton in the Highland Rim area. Fleabanes were also thought to be the most important hosts that influenced early season plant bug populations in cotton in the Delta of Arkansas (Tugwell et al. 1976) and Mississippi (Cleveland 1982). Two species of fleabane, *E. annuus* and *E. philadelphicus* L., bloom and are attractive to plant bugs in April, May, and June in the mid-South and are reproductive hosts for the first generation of adults that developed on other wild hosts in March and April (Snodgrass 2003). Treatment of fleabane and other wild hosts with herbicides could kill nymphs and eggs laid in the hosts, but the adults would move to other hosts, including cotton. Herbicide treatment of the wild hosts on which the first generation adults developed in March and April could be a better control strategy.

Our objective in this study was to determine the effect of a single herbicide application in early season (March and April) on broadleaf weed density and tarnished plant bug populations on them. The application was made as part of a large experiment that determined that destruction of wild hosts in early season significantly reduced subsequent tarnished plant bug populations in cotton grown in 23-km$^2$ treated areas in the Mississippi River Delta (Snodgrass et al. 2003).

## Materials and Methods

**Herbicide Treatment of Broadleaf Wild Hosts.** The experiment was conducted in 1999–2001 in Bolivar, Sunflower, and Washington Counties in the Delta of Mississippi. In each of the 3 yr, four approximately square test sites of 4.8 km (3 mi) on a side were used in the test. Two of the test sites were checks and received no treatment each year. Little is known about how far plant bugs move, and to determine if removal of broadleaf early-season wild hosts affected plant bugs in a treated area, we used the biggest areas we could treat and sample. In the two treated test sites, a single application of the herbicide Trimec® (PBI/Gordon, Kansas City, MO) in 1999 or Strike 3™ (Agriliance, St. Paul, MN) in 2000 and 2001 was made. Trimec and Strike 3 both contain 2, 4-d (1.11 kg), mecoprop (0.27 kg), and dicamba (0.10 kg) as active ingredients per 3.79 liter (1 gal.) of formulated product. Trimec or Strike 3 was applied so that each ha of marginal area treated received 0.68, 0.08, and 0.06 kg of 2, 4-d, mecoprop, and dicamba, respectively. Applications were made using John Deere 6400 and 2355 tractors (John Deere®, Moline, IL). A John Deere 6400 was fitted with an 18.3-m spray-boom having 36 cone TeeJet (AI) 110025 VP low-drift nozzles, calibrated to deliver 93.5 liter/ha at 27.2 kg/6.45 cm$^2$. A John Deere 640 tractor had a front-mounted boom 1.83 m in length with a model 187 spray nozzle (Evergreen Products, Millen, GA) mounted on the boom end. This nozzle is designed for spraying road sides and can produce a spray swath up to 5.9 m wide. A rear boom 3.1 m in length was fitted with eight cone TeeJet (AI) 110025 low-drift nozzles and was used to treat behind the tractor. The two spray booms were controlled separately, and both were calibrated to deliver 121.5 liter/ha at 18.2 kg/6.45 cm$^2$. The herbicide application was made to all margins in the treated areas in which wild hosts were present. The application was made in the first 2 wk of April in 1999 and in the first 2 wk of March in 2000 and 2001. Records on the amount of herbicide used in each year were kept to estimate the number of hectares of wild host plants treated.

**Sample Sites and Methods.** In 1999 and 2000, the same treated and check test sites were used. The two treated test sites were located near Tribbett and Dunleith in Washington County, MS, whereas the two check test sites were near Hollandale in Washington County and Kenlock in Sunflower County. The test site near Tribbett was used as a check site in 2001, whereas the second check site was located near Choctaw in Bolivar County. The two treated test sites in 2001 were located near Arcola and Holly Ridge in Washington County. Each of the four test sites was divided into approximately equal quadrants for sampling purposes. Marginal areas with good stands of wild hosts extending at least 100 m in length were identified and marked on aerial maps of the four test sites. These maps were obtained from the Geographic Information Satellite Center at the Delta Research and Extension Center, Stoneville, MS. The identified marginal areas with good stands of host plants were used for sampling plant bugs and to determine host plant species and densities before and after the herbicide treatment. The number of marginal areas sampled in each of the four test areas varied and depended on the number of roads and ditches present along with the cultural practices of the growers. At least one marginal area was sampled in each quadrant of the four test areas in each year. Samples were taken at four locations in each of the marginal sample areas. The distance from the edge of each marginal sample area to the first location sampled, and the distances between the next three sample locations ranged from 5 to 25 m and were selected at random. At each sample location, a rope 7.62 m in length marked in 0.31-m intervals was placed lengthwise through the middle of the area of wild hosts being sampled. Wild hosts were sampled for tarnished plant bugs with a sweep net and the numbers of adults and nymphs captured per 10 sweeps taken were recorded. No effort was made to separate numbers of plant bugs captured by host, because the host plants usually occurred in mixed stands. Sweep net samples were taken before taking plant density counts

**Table 1. Effect of an herbicide treatment in early April 1999 and early March 2000 and 2001 on tarnished plant bug wild host plant density in marginal areas near roads, fields, and ditches in the Mississippi Delta**

| Year | Experimental site[a] | Pretreatment (mean no/m$^2$) | Posttreatment (mean no/m$^2$) | Percent reduction | $P^b$ |
|---|---|---|---|---|---|
| 1999 | Treated 1 | 37.9a | 6.1b | 84 | 0.001 |
| | Treated 2 | 17.6b | 2.4b | 86 | 0.001 |
| | Check 1 | 29.9a | 26.0a | 13 | 0.257 |
| | Check 2 | 30.3a | 22.7a | 25 | 0.028 |
| 2000 | Treated 1 | 47.4bc | 3.9c | 92 | 0.001 |
| | Treated 2 | 35.4c | 3.0c | 92 | 0.001 |
| | Check 1 | 111.5a | 85.0a | 24 | 0.002 |
| | Check 2 | 58.5b | 51.6b | 12 | 0.419 |
| 2001 | Treated 1 | 81.8ab | 1.1a | 99 | 0.001 |
| | Treated 2 | 64.3b | 4.5a | 93 | 0.001 |
| | Check 1 | 100.3a | 33.5b | 66 | 0.001 |
| | Check 2 | 82.7ab | 57.8b | 30 | 0.028 |

Means in a column for each year not followed by the same letter are significantly different based on least significant difference comparisons ($P \leq 0.05$).

[a] In 1999 and 2000, treated sites 1 and 2 were located at Tribbett and Dunleith, respectively, whereas check sites 1 and 2 were located at Kenlock and Hollandale, respectively. In 2001, treated sites 1 and 2 were located at Arcola and Hollandale, respectively, whereas check sites 1 and 2 were located at Tribbett and Choctaw, respectively.

[b] The error probabilities for comparing pretreatment and posttreatment means at the same test site. Their values are based on the error estimates from the ANOVA, and their use is equivalent to using least significant difference comparisons.

to avoid disturbing plant bugs on the hosts before they were sampled. Sweep net sampling in 1999 to determine plant bug populations was performed about 2 wk after the herbicide treatment was made. In 2000 and 2001, sweep net sampling for plant bugs began ~3 wk after the herbicide treatment was made and was repeated at 2-wk intervals through mid-May. A minimum of 16 sweep net samples (at least four samples in each quadrant) were taken on each sample date in each year in each of the four test areas.

Host density was determined by counting the broadleaf plants known to be plant bug hosts within a wire ring that encompassed an area of 0.25 m$^2$. Counts were recorded by plant species and were taken at four places along the 7.62-m rope by random selection of 4 of the 25 distances marked at 0.31-m intervals along the rope. The ring was laid beside the rope at each distance selected and the counts taken. Placement of the ring on the left or right side of the rope was also selected at random for each of the four counts. Sampling to determine host plant and tarnished plant bug density was performed before the herbicide treatment and after treatment in all four test sites. Host plant densities were determined again at 3–4 wk after treatment. A minimum of 16 host plant density counts (at least 4 counts in each quadrant) were taken in each test area on the pretreatment and posttreatment sample dates. For statistical analyses, numbers of the most abundant host plant species found each year were summed for means. The most abundant broadleaf tarnished plant bug hosts found in the samples were narrowleaf vetch, *Vicia angustifolia* Reichard; henbit, *Lamium amplexicaule* L.; sour dock, *Rumex crispus* L.; spotted burclover, *Medicago arabica* L.; sheperd's purse, *Capsella bursa-pastoris* L. Medicus; cutleaf geranium, *Geranium dissectum* L.; cutleaf evening-primrose, *Oenothera laciniata* Hill; showy evening-primrose, *O. speciosa* Nuttall; caley pea, *Lathyrus hirsutus* L.; buttercup, *Ranunculus* spp.; chickweed, *Stellaria media* L. Cyrillo; and white clover, *Trifolium repens* L. Voucher specimens of the wild host plants are deposited in the SWSL Herbarium, Southern Weed Science Research Unit, USDA-ARS, Stoneville, MS.

**Statistical Analyses.** Experimental design was a split plot where the main unit had two treatments with two replications arranged in a completely random design. Time (the pretreatment and posttreatment samples) was treated as a subunit in the analyses. Quadrants and marginal sample areas were treated as subsamples for the main unit treatment effects and as replications for the time effect. Data were analyzed using analysis of variance (ANOVA) and the MIXED model procedure of SAS (SAS Institute 1999). A $P$ value is given in Tables 1 and 2 for each comparison between pretreatment and posttreatment means. Its value is based on the error estimate from the ANOVA, and declaring significance at $P < 0.05$ is equivalent to using a least significant difference (LSD) comparison.

**Table 2. Mean no. tarnished plant bugs found on wild host plants in marginal areas near fields, roads, and ditches, untreated and treated with a herbicide in the Mississippi Delta**

| Year | Sample area | Life stage | Pretreatment [mean[a] no. ($P$ value[b]) per 10 sweeps] 28 March | Posttreatment [mean[a] no. ($P$ value[b]) per 10 sweeps] 29 April |
|---|---|---|---|---|
| 1999 | Treated | Nymph | 0.114 | 0.193 (0.55) |
| | Check | Nymph | 0.172 | 0.146 (0.83) |
| | Treated | Adult | 0.214 | 0.612 (0.17) |
| | Check | Adult | 0.026 | 0.563 (0.09) |

[a] Means are based on samples from two check or two treated test sites. Treated test sites received an application of Trimec® (1999) or Strike 3J™ (2000 and 2001) herbicide in the week after the pretreatment sample date.

[b] Posttreatment means were compared with pretreatment means in the treated or check areas. The $P$ value is based on the error estimate from the ANOVA and is equivalent to using a least significant difference comparison.

**Laboratory Rearing of Tarnished Plant Bugs on Italian Ryegrass.** In the herbicide-treated test areas, the most abundant plant species after treatment in all 3 yr was Italian ryegrass, *Lolium multiflorum* Lamarck. In addition, tarnished plant bug adults and nymphs were found in sweep net samples at sample sites in treated areas where Italian ryegrass was the only plant species sampled. To help determine the importance of ryegrass as a plant bug host, four laboratory tests were conducted. In test 1, newly hatched tarnished plant bug nymphs (which had hatched during the previous 24 h) were placed into a plastic container (0.47 liter) whose top had been replaced with organdy cloth. The nymphs were from a laboratory colony maintained at the Southern Insect Management Research Unit, USDA-ARS, Stoneville, MS. Nymphs in this colony are reared on broccoli, *Brassica oleracea* L. variety botrytis L. Newly hatched nymphs were fed broccoli, flower buds and flowers of daisy fleabane, *Erigeron philadelphicus* L. (a good reproductive wild host of plant bugs; Snodgrass et al. 1984a), or floral spikelets of Italian ryegrass. The food was changed daily, at which time mortality or development to adult was recorded. The insects were reared at 30 ± 1°C with a photoperiod of 14:10 (L:D). Each of the three food treatments had five replications (plastic containers with 10 nymphs). Test 2 was identical to test 1 except the food treatments did not include daisy fleabane, and third-instar nymphs were used to start the test. The food treatments in tests 3 and 4 were ryegrass stems and leaves or broccoli. Rearing conditions, containers, and data collection were identical in tests 3 and 4 to test 1. Newly hatched nymphs (test 3) and third-instar nymphs (test 4) were reared, and the two food treatments had five replications (plastic containers with five nymphs). Experimental design was a randomized complete block with subsampling to analyze the mean number of days for nymphs to become adults and mean percent survival. Results were analyzed using ANOVA and the MIXED model procedure of SAS (SAS Institute 1999). Significance was declared at $P < 0.05$, and LSMEANS was used to determine treatment differences.

**Tarnished Plant Bug Oviposition on Italian Ryegrass.** To determine if tarnished plant bugs would oviposit in ryegrass, ryegrass was transplanted from a field border at Stoneville during November 2004 into six pots (4.5 liter) and placed in a greenhouse at 14:10 h (L:D) at 25 ± 4°C. An additional six pots of ryegrass from the field border were established in the greenhouse 2 wk later. Each pot contained 15–20 plants, and when floral spikelets were produced by the first group of plants placed in the greenhouse, an organdy cage was placed over each of four pots. Cages were also placed over each of four pots of ryegrass from the second group of plants placed in the greenhouse. The ryegrass in these pots was not blooming. Each organdy cage were supported by wooden dowels (1.0 cm in diameter by 46 cm in length) pushed into the potting soil and was attached to the rim of the pot using carpet tape. Into each of the eight cages, five female and two male plant bugs were released. The plant bugs were 10–12 d old, and all the females were egg laying. This was determined by caging the females individually for 24 h in 20-ml glass vials in which a 2-cm piece of green bean pod, *Phaseolus vulgaris* L., was placed. Only females that oviposited into the green bean pods were used in the test. The adults were left in the cages for a 6-d period. The cages were then removed, and the ryegrass plants in each pot were cut at the soil line and examined in the laboratory under magnification to see if eggs had been deposited.

## Results

**Herbicide Treatment of Broadleaf Wild Hosts.** In 1999, 2000, and 2001, an estimated 314, 273, and 202 ha of wild hosts were treated. Expressed as a percentage of the 4,664 hectares found in two 23-km$^2$ treated areas, 6.7, 5.9, and 4.3% of the total area was treated in 1999, 2000, and 2001, respectively. The single herbicide application was effective in reducing numbers of broadleaf host plants found in the treated test sites. The pretreatment host plant density was significantly higher than the posttreatment host plant density in the treated test sites in all 3 yr (Table 1). The posttreatment plant densities were 84–99% lower than the pretreatment plant densities in the treated areas during the 3 yr of the test. Significant differences were found in pretreatment plant densities in the four test areas in all 3 yr of the study. Comparison of pretreatment plant densities among the four test sites in 1999 found that treated site 2 (Dunleith) had a significantly lower plant density than the other three test sites. Check site 1 (Kenlock) had a significantly higher pretreatment host plant density in 2000 than the other three test sites. Pretreatment plant density in check site 1 (Tribbett) in 2001 was significantly higher than pretreatment plant densities in treated site 2 (Holly Ridge). In the check test sites, pretreatment plant density declined significantly (25%) compared with posttreatment density in check test site 2 (Hollandale) in 1999. A significant decline of 24% occurred at check test site 1 (Kenlock) in 2000, and in both checks (66 and 30%) in 2001. These declines were the result of the natural maturation and senescence of winter hosts such as henbit and shepherd's purse, and senescent hosts were not counted in the posttreatment counts. Despite the natural decline in host plant density, plant densities were still significantly higher in the posttreatment counts in the checks compared with the posttreatment densities in the treated test sites in 1999, 2000, and 2001.

In all 3 yr of the study, posttreatment sweep net samples of wild hosts for tarnished plant bugs in the treated test sites were mainly sweeps from Italian ryegrass that was not affected by the herbicide treatment. Tarnished plant bug adults and nymphs were found in posttreatment samples of ryegrass in some of the treated test sites, which indicated that tarnished plant bugs were using ryegrass as a host. No significant differences were found in numbers of plant bug nymphs and adults when posttreatment numbers captured were compared with pretreatment numbers

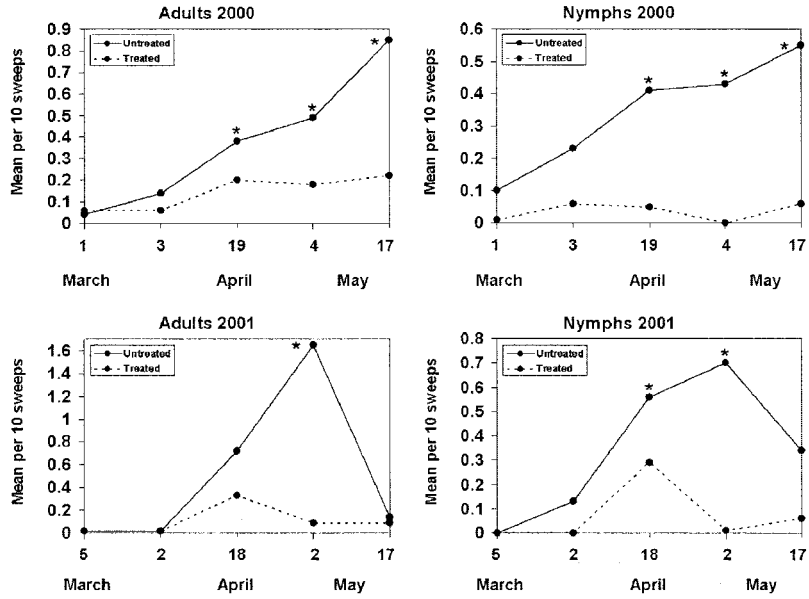


**Fig. 1.** Mean numbers of tarnished plant bug found on wild host plants in marginal field areas that were untreated or treated with a herbicide in the Mississippi Delta. Posttreatment means with an * are significantly higher than the pretreatment mean (means found on 1 March 2000 and 5 March 2001). Each comparison is based on the error estimate from the ANOVA and is equivalent to using a LSD comparison.

captured in the treated and check test sites in 1999 (Table 2). However, mean numbers of plant bug adults and nymphs were higher in the posttreatment counts in the treated test sites than they were in the check test sites.

In 2000 and 2001, posttreatment means of plant bug adults and nymphs were never significantly different from pretreatment means in any week in the treated test sites (Fig. 1). Numbers of adults and nymphs found in the posttreatment means in the check test sites were significantly higher than the pretreatment means in the check test sites from 19 April through 17 May, 2000. In 2001, posttreatment means in the check test sites were significantly higher for nymphs compared with pretreatment means on 18 April and 2 May, whereas adults were significantly higher on 2 May. On all but one sample date (2 April, 2001), mean numbers of adults and nymphs were higher each week in the check areas. Mean numbers of adults and nymphs found in the check also increased each week from the previous week on all but one date (17 May 2001). This did not occur for adults and nymphs in the treated areas. Averaging adults and nymphs together over the four posttreatment samples in each year produced means of 0.870 and 0.205 per 10 sweeps for check and treated areas, respectively, in 2000; and 1.063 and 0.207 per 10 sweeps for check and treated areas, respectively, in 2001. Comparison of these means showed that tarnished plant bug populations were 4.2- and 5.1-fold higher in the check areas in 2000 and 2001, respectively.

**Laboratory Rearing of Tarnished Plant Bugs on Italian Ryegrass.** When placed on Italian ryegrass as first instars, tarnished plant bugs had a significantly longer ($F = 40.4$; df = 2,13; $P = 0.0001$) developmental time to adult compared with rearing them on broccoli or daisy fleabane (Table 3). Development on ryegrass required ≈1 d longer than on daisy fleabane and 2.5 d longer than on broccoli. The percentage of first instars that developed into adults when reared on ryegrass (56%) was also significantly lower ($F = 3.62$; df = 2,147; $P = 0.03$) than the percentages that became adults when reared on broccoli (78%) or daisy fleabane (76%). No significant differences ($F = 0.02$; df = 1,98; $P = 0.89$) were found in the developmental times to adult for third instars reared on Italian ryegrass in test 2 compared with third instars reared on broccoli (Table 3). The percentage of third instars that became adults when reared on ryegrass (92%) was not significantly different ($F = 0.70$; df = 1,98; $P = 0.40$) than

**Table 3. Results from rearing tarnished plant bugs on Italian ryegrass, broccoli, and daisy fleabane beginning with first- or third-instar nymphs**

| Treatment[a] | Mean no. days to adult | Percent becoming adults |
|---|---|---|
| Test 1 | | |
| Broccoli | 11.66 ± 0.19a | 78.0 ± 0.06a |
| Daisy fleabane | 13.12 ± 0.19b | 76.0 ± 0.06a |
| Italian ryegrass (blooms) | 14.21 ± 0.22c | 56.0 ± 0.05b |
| Test 2 | | |
| Broccoli | 5.34 ± 0.21a | 96.0 ± 0.03a |
| Italian ryegrass (blooms) | 5.30 ± 0.21a | 92.0 ± 0.03a |

Means ± SEM followed by the same letter in the same column are not significantly different (LSD test with $\alpha = 0.05$).

[a] First-instar nymphs were reared in test 1, whereas third-instar nymphs were reared in test 2.

the percentage that became adults when reared on broccoli (96%). In test 3, none of the first instars reared on ryegrass stems and leaves became adults, whereas 84% of the control nymphs reared on broccoli became adults. These adults required an average 11.81 ± 0.13 (SE) d to become adults. The nymphs reared on ryegrass had one nymph that reached the fourth instar and four nymphs that reached the fifth instar before they died. The longest any nymph survived was 25 d. None of the third instars reared on ryegrass leaves and stems became adults, whereas 88% of the control nymphs reared on broccoli became adults in test 4. These adults required an average 5.16 ± 0.13 d to become adults. All of the nymphs reared on ryegrass died as fourth or fifth instars. The longest any nymph survived was 11 d.

**Tarnished Plant Bug Oviposition on Italian Ryegrass.** A total of 83 eggs were found to have been oviposited in the blooming ryegrass over the 6-d period. This was an average of 4.2 eggs per female for the 20 females caged five per pot on the four pots of ryegrass. Most eggs (66) were laid in leaves; the remainder were laid in stems (4), flowers (1), or in stems holding flowers (12). A total of six females and no males were alive in the cages when they were removed. In the nonflowering ryegrass, a total of 36 eggs were found for an average of 1.8 eggs per female for the 20 females used in the pots of ryegrass. Most eggs (32) were laid in leaves; the remainder (4) were laid in stems. A total of 10 females and 4 males were found alive in the pots when the cages were removed.

## Discussion

Variation in the density of broadleaf wild hosts found in the pretreatment counts in the test areas was large enough to produce significant differences in pretreatment densities in all 3 yr. A wide variety of unmeasured factors, natural and manmade, could have caused these differences. The single application of Trimec or Strike 3 herbicide was effective in eliminating most broadleaf plants in the treated areas in all 3 yr. However, these herbicides had no effect on grasses. Italian ryegrass was abundant in the treated and check test areas in all 3 yr, and in each year, it flowered in late April and May. In 1999, the herbicide application was made during the first 2 wk of April, and it destroyed most of the broadleaf hosts in the treated areas and left ryegrass as the most abundant host in bloom in these areas. Mean numbers of tarnished plant bug adults and nymphs were higher in samples taken mainly from ryegrass in the treated test sites on the posttreatment sample date than were mean numbers found in the check test sites in samples from all host plants present on the posttreatment sample date (Table 2). Field observations taken on ryegrass in the treated test sites on the posttreatment sample date found plant bug nymphs and adults on the ryegrass flowers and seeds. This indicated that plant bugs were using ryegrass as a previously unreported host. Either plant bugs were ovipositing in the rye grass, or nymphs had crawled onto the ryegrass as broadleaf hosts died from the herbicide. The laboratory test in which female plant bugs were caged on flowering or nonflowering ryegrass showed that female plant bugs would oviposit in ryegrass (with or without blooms) when given no choice over a 6-d period. So, use of ryegrass as a reproductive host into which eggs were laid could have occurred in the field study. However, development of nymphs from eggs which hatched on ryegrass that was not in bloom into adults would probably be very low, because none of the first or third instars became adults when reared on nonflowering ryegrass in the laboratory test. This would also probably be the case in the field if third instars were forced onto nonflowering ryegrass as their broadleaf hosts died because of herbicide use. Similar results were reported by Abel and Snodgrass (2003). They reared newly emerged plant bug nymphs on different plant parts of corn, *Zea mays* L, which is also a grass. No nymphs became adults when reared on corn leaves. Survival of newly emerged and third-instar nymphs on flowering ryegrass occurred, and 56 and 92%, respectively, became adults in the laboratory tests. The occurrence of plant bug nymphs on plant tissue that includes buds and flowers is commonly observed in the field, and nymphs are seldom collected from any plant host unless blooms, flower buds, or fruit are also present (Snodgrass et al. 1984a). The discovery that ryegrass was a tarnished plant bug host changed our timing of the herbicide application in 2000 and 2001. The application was made a month earlier during the first 2 wk of March in both years. This eliminated broadleaf weeds, and whereas ryegrass was still present in the treated areas, it was not flowering and probably did not serve as a reproductive host for plant bugs. Its role as a reproductive host when it flowered during April and May was less important than that of broadleaf hosts. Tarnished plant bug populations in April and May increased significantly in the check areas on ryegrass and broadleaf hosts, whereas their populations on ryegrass in the treated areas did not (Fig. 1).

Reproductive diapause in the tarnished plant bug in the mid-South is broken in overwintering adults beginning in December (Snodgrass 2003). Nymphs can be collected on broadleaf winter hosts in January. During winters with average or above average temperatures, new generation adults can be found by mid-March, whereas new generation adults are not found until mid-April in cold winters. Winter temperatures affect the growth of suitable hosts and therefore affect when the first generation of plant bugs will be produced. Thus, late-February through mid-March is the best time for herbicide treatment of early-season wild hosts, because treatment at this time kills hosts on which nymphs are developing or in which eggs have been laid in average or mild winters. In cold winters, the herbicide treatment will kill developing hosts on which plant bug reproduction would occur in March and April.

In summary, this study showed that a single herbicide application made in the first 2 wk of March was effective in reducing broadleaf hosts of tarnished plant

bugs in marginal areas near roads, ditches, and fields in the Delta. Tarnished plant bug populations did not increase in numbers in these areas compared with untreated areas.

## Acknowledgments

The authors thank D. Boykin for assistance in the treatment of data and analyses of results. The expert assistance of D. Adams, C. Lanford, A. Patterson, J. Cambell, and T. Stanrod in treating and sampling the test areas is also gratefully acknowledged.

## References Cited

**Abel, C. A., and G. L. Snodgrass. 2003.** The development of tarnished plant bugs on various corn tissue. Proceedings of the Beltwide Cotton Conference, Nashville, TN, 6–10 January 2003.

**Atanassov, A., P. W. Shearer, G. Hamilton, and D. Polk. 2002.** Development and implementation of a reduced risk peach arthropod management program in New Jersey. J. Econ. Entomol. 95: 803–812.

**Cleveland, T. C. 1982.** Hibernation and host plant sequence studies of tarnished plant bugs, *Lygus lineolaris*, in the Mississippi Delta. Environ. Entomol. 11: 1049–1052.

**Crosby, C. R., and M. D. Leonard. 1914.** The tarnished plant bug, *Lygus pratensis* Linnaeus. Bull. Cornell Univ. Agric. Exp. Stn. 346: 461–526.

**Fleischer, S. J., and M. J. Gaylor. 1987.** Seasonal abundance of *Lygus lineolaris* (Heteroptera: Miridae) and selected predators in early season uncultivated hosts: implications for managing movement into cotton. Environ. Entomol. 16: 379–389.

**Hardman, J. M., K.I.N. Jensen, D. L. Moreau, J. L. Franklin, and E. D. Bent. 2004.** Effects of ground cover treatments and insecticide use on population density and damage caused by *Lygus lineolaris* (Heteroptera: Miridae) in apple orchards. J. Econ. Entomol. 97: 993–1002.

**Hollingsworth, R. G., D. C. Steinkraus, and N. P. Tugwell. 1997.** Response of Arkansas populations of tarnished plant bugs (Heteroptera: Miridae) to insecticides and tolerance differences between nymphs and adults. J. Econ. Entomol. 90: 21–26.

**Killian, J. C., and J. R. Meyer. 1984.** Effect of orchard weed management on catfacing damage to peaches in North Carolina. J. Econ. Entomol. 77: 1596–1600.

**Pankey, J. H., B. R. Leonard, J. B. Graves, and E. Burris. 1996.** Toxicity of acephate, cypermethrin, and oxamyl to tarnished plant bugs in vial bioassays and cage studies on cotton. Proceedings of the Beltwide Cotton Product Research Conference. National Cotton Council of America, Memphis, TN.

**SAS Institute. 1999.** SAS/STAT user's guide, version 8. SAS Institute, Cary, NC.

**Snodgrass, G. L. 1996.** Insecticide resistance in field populations of the tarnished plant bug (Heteroptera: Miridae) in cotton in the Mississippi Delta. J. Econ. Entomol. 89: 783–790.

**Snodgrass, G. L. 2003.** Role of reproductive diapause in the adaption of the tarnished plant bug (Heteroptera: Miridae) to its winter habitat in the Mississippi River Delta. Environ. Entomol. 32: 945–952.

**Snodgrass, G. L., and G. W. Elzen. 1995.** Insecticide resistance in a tarnished plant bug population in cotton in the Mississippi Delta. Southwest. Entomol. 20: 317–323.

**Snodgrass, G. L., W. P. Scott, and J. W. Smith. 1984a.** Host plants and seasonal distribution of the tarnished plant bug (Heteroptera: Miridae) in the delta of Arkansas, Louisiana, and Mississippi. Environ. Entomol. 13: 110–116.

**Snodgrass, G. L., W. P. Scott, and J. W. Smith. 1984b.** An annotated list of the host plants of *Lygus lineolaris* (Heteroptera: Miridae) in the Arkansas, Louisiana, and Mississippi Delta. J. Georgia Entomol. Soc. 19: 93–101.

**Snodgrass, G. L., E. A. Stadelbacher, and J. W. Smith. 1991.** Distribution and abundance of early season wild host plants and bollworm and tobacco budworm populations (Lepidoptera: Noctuidae) in an intensively cropped area of the mid-delta of Mississippi. J. Entomol. Sci. 26: 9–16.

**Snodgrass, G. L., W. P. Scott, J. T. Robbins, and D. D. Hardee. 2003.** Suppression of tarnished plant bugs in cotton by treatment of early season wild host plants with herbicides in nine-square-mile areas of the Mississippi Delta. Proceedings of the Beltwide Cotton Conference, Nashville, TN, 6–10 January 2003.

**Tugwell, P., S. C. Young, Jr., B. A. Dumas, and J. R. Phillips. 1976.** Plant bugs in cotton: importance of infestation time, types of cotton injury, and significance of wild hosts near cotton. University of Arkansas Agricultural Experiment Station Bull. Rep. Ser. 227: 1–24.

*Received for publication 15 June 2004; accepted 27 March 2005.*